A Rigid Point Set Registration of Remote Sensing Images Based On Genetic Algorithms & Hausdorff Distance

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Abstract**—**Image registration is the process of establishing point by point correspondence between images obtained from a same scene. This process is very useful in remote sensing, medicine, cartography, computer vision, etc. Then, the task of registration is to place the data into a common reference frame by estimating the transformations between the data sets. In this work, we develop a rigid point registration method based on the application of genetic algorithms and Hausdorff distance. First, we extract the feature points from both images based on the algorithm of global and local curvature corner. After refining the feature points, we use Hausdorff distance as similarity measure between the two data sets and for optimizing the search space we use genetic algorithms to achieve high computation speed for its inertial parallel. The results show the efficiency of this method for registration of satellite images.

Keywords**—**Feature extraction, Genetic algorithms, Hausdorff distance, Image registration, Point registration.

I. Introduction

IMAGE registration is the process of overlying two or more images of the same scene taken at different times, from different viewpoints and/or by different sensors [1]. This has many applications in many fields as diverse as medical images analysis, pattern matching and computer vision for robotics, as well as remotely sensed data processing [2], [3].

The major registration purpose is to remove or suppress geometric distortions between the reference and sensed images, which were introduced due to different imaging conditions, and thus to bring images into geometric alignment. Image registration methods can be categorized in different ways according to different perspectives. According to the information used for registration, they can be grossly classified into the area-based and the feature-based. Feature-based methods utilize extracted features including regions, corners, lines or curves and points estimate the registration parameters.

Point set representation of image data, e.g. feature points, is commonly used in many applications. The *iterative closest point* (ICP) algorithm [4] is one of most common approaches of feature-based image registration and shape matching problem because of its simplicity and performance. Nonetheless, it has its own limitations. The non-differentiable cost function associated with ICP introduces the local convergence problem which requires sufficient overlap between the data-sets and a close initialization. Also, a naive implementation of ICP is known to be prone to outliers which prompted several more robust variations [5], [6].

In recent years, genetic algorithms (GAs) have been intensively investigated and applied to many optimization problems [8]. GAs are especially appropriate for the optimization in large search spaces, which are unsuitable for exhaustive search procedures. GAs do a trade-off between the exploration of the search space and the exploitation of the best solutions found so far. However, GAs only provide near-optimal solutions which are often satisfactory in practical applications. This disadvantage is compensated by the ability of a GA to find a global solution in a large optimization space as opposed to classical optimization procedures which tend to find a local solution.

While the application of genetic algorithms in 2D-3D registration methods has not been significant so far, several methods use genetic techniques to register 3D data or range images. Jacq and Roux [9] use GAs for registration of 3D medical images. Brunnström and Stoddard [10] used a GA to find an initial guess for the free-form matching problem that is finding the translation and the rotation between an object and a model surface. In work of Stamos and Leordeanu [11] a feature-based registration approach, which searches line and plane pairs in 3D point cloud space instead of 2D intensity image space, has been adopted.

In this paper, we propose a point registration method based on the genetic algorithms for satellite images. This procedure is focused on the problem of obtaining the best solution between two sets data points through a robust search method with Hausdorff distance matching. The remainder of paper is organized as follows: the second topic presents the method of extraction the point features from image.

The third topic gives the formulation of the Hausdorff distance. The fourth topic describes the component of GAs used for registration: the chromosome encoding and the model of transformation adopted to optimise the parameters. The simulation results are presented in the fifth topic, and last we finalize with conclusion.

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II. Feature Points Extraction

The registration process is usually carried out in four steps. The first step consists of selection of features on the images. Next, each feature in one image is compared with potential corresponding features in the other one. A pair of points with similar attributes is accepted as matches and they are called control points. Finally the parameters of the best transformation which models the deformation between both images are estimated using the control points obtained in the previous step [3].

To obtain precise registration, a large number of control points must be selected across the whole image. In this paper, to extract the control points, we used the approach of corner proposed by [12] which considers both global and local curvature of corners in the detection that detects both fine and coarse features accurately. This method presents a significant advantages compared to SIFT algorithm as increases the number of true corners detected and reduces the number of false corners detected which is necessary to detect true point feature in our method. This algorithm of detection of corners is summarized as follows:

Step 1. Detect edges using Canny edge detector to obtain a binary edge map.

Step 2. Extract contours after compute the curvature at a fixed low scale for each contour to retain the true corners, and regard the local maxima of absolute curvature as corner candidates.

Step 3. Compute a threshold adaptively according to the mean curvature within a region of support. Round corners are removed by comparing the curvature of corner candidates with the adaptive threshold.

Step 4. Based on a dynamically recalculated region of support, evaluate the angles of the remaining corner candidates to eliminate any false corners.

Step 5. Finally, consider the end points of *open* contours, and mark them as corners unless they are very close to another corner.

An example of feature points extracted following this method is illustrated in Fig. 1.

After the step of feature extraction, the second step is *Feature points matching* in order to refine the control points and remove the false matching.

A correspondence mechanism between the feature points sets detected from the images to be registered must be established. In this proposed algorithm, Normalized Cross-correlation method based similarity measure is used to establish the correspondence between these two points sets. This correspondence is evaluated using a circular neighborhood of radius R centered on each feature point. For each feature point from reference image is compared with all the features points in the sensed image. The point in the sensed image that has the maximum correlation coefficient with the point of the image reference is the corresponding point.

Detected corners   Edge map

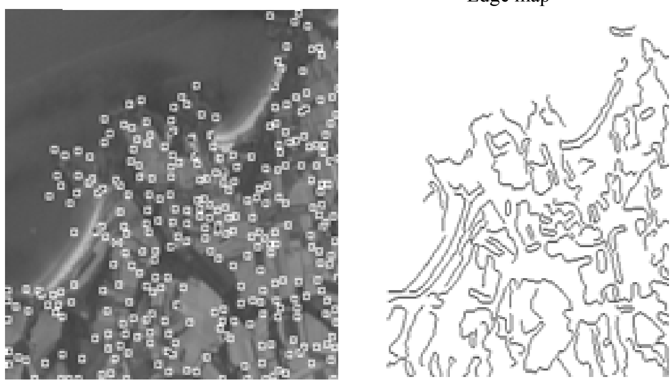


Fig. 1 An example of Feature points extraction of the reference image: in the right edge map with canny edge; and in the right corners detected

III. Hausdorff Distance Matching

Due to the existence of noise and the disparity of dissimilar imaging modalities, outliers and missing features are inevitable in feature extraction, which means establishing feature correspondence is generally no easy task. So it might be beneficial for us to solve for the spatial transformation while not having to establish a feature correspondence relationship. One alternative is the Hausdorff distance-based methods. These methods have been successfully applied to rigid registration problems and are robust to outliers and missing features [13].

Given two finite point sets $A = \{a_1, \dots, a_p\}$ and $B = \{b_1, \dots, b_q\}$, the Hausdorff distance is defined as

$$H(A,B) = max\left(h(A,B), h(B,A)\right) \qquad (1)$$

where

$$h(A,B) = \max_{a\in A} d(a,B)$$
$$d(a,B) = \min_{b\in B} d(a,b) \qquad (2)$$

The function $h(A,B)$ is called the directed Hausdorff distance from A to B. it identifies the point $a \in A$ that is farthest from any point of B and measures the distance from a to its nearest neighbor in B, that it is $h(A,B)$ in effects ranks each point of A based on its distance to the nearest point of B and then uses the largest ranked such point as the distance.

The Hausdorff distance $H(A,B)$ is the maximum of $h(A,B)$ and $h(B,A)$. Thus it measures the degree of mismatch between two sets by measuring the distance of the point A that is farthest from any point of B and vice versa [7].

For image processing applications it has proven useful to apply a slightly different measure named the modified Hausdorff distance for comparing two points sets extracted from the corresponding gray-scale images. The modified version of the classical Hausdorff distance introduced by Dubuisson et al. [14] also known as mean Hausdorff distance take into account the mean distance between the two sets of points instead of the maximum distance only. It is formulated as follows:

$$H(A,B)_{mod} = \frac{\sum \max_{a\in A}\{\min_{b\in B} d(a,b)\}}{n_A} \quad (3)$$

where nA is the total number of points in set A.

IV. GAs Based Image Registration

A GA is a search technique used in computing to find exact or approximate solutions to optimization and search problems. GAs are categorized as global search heuristics based on the evolutionary idea of genetics and natural selection. GAs are implemented as a computer simulation in which a population of candidate solutions to an optimization problem evolves toward better solutions. Traditionally, solutions are represented in binary as strings, but other encodings are also possible. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population.

A. Chromosome Encoding

In relation to image registration, every individual represents a combination of all transformation parameters which describes image transformation. Therefore, the vector of parameters (R, X, Y) is used as a chromosome that participates in an iterative process. A bit encoding is adopted to represent a chromosome as shown in Fig. 2. An 8-bit field is used to represent the possible relative rotation of the input image to the reference image; and 6 bits are used to express the translation in the x-axis and the y-axis. Thus the length of each chromosome is 20 bits.

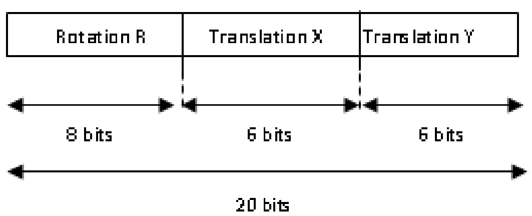


Fig. 2 Encoding of chromosome into 20 bits corresponding to the transformation parameters

All representations are signed magnitude, using one bit for the sign and the rest of the bits to represent the magnitude of the rotation or translation. Thus, the relative rotation has the range of ±128 degrees, while relative translation in the x or y direction has the range of ±32 pixels.

B. Objective Function

A GA uses a fitness function to determine the performance of each artificially created chromosome; therefore the fitness function should measure the registration quality of each chromosome. Formally, given two finite size point sets, the *model* set M and the *scene* set S, our registration method finds the parameters of a transformation T which minimizes the cost function.

Then, in this work, we adopt this modified Hausdorff distance, given in (3), as objective function of GAs which will be *minimized*. We assume that the type of transformation is rigid with three parameters: rotation and translation in both x and y directions. For the data point in the model image with coordinates x, y and intensity value I, and its image is x', y', and I', that are related by the mapping given in the following equation:

$$Pt = R * p_i + T \quad (4)$$

where,

$p_i\,(x, y)$ is a source point

$Pt\,(x', y')$ its transformed corresponding point

$R = \begin{bmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$ is a rotation matrix

$T = \begin{bmatrix} Tx \\ Ty \\ 0 \end{bmatrix}$ is a translation vector.

Given the model mapping of the transformation which can be matching the two point sets with Hausdorff distance; and the encoding the chromosome considered, we can apply the GA process to optimize the transformation parameters.

V. Simulation Results

The reference image is a SPOT panochromatic image. The second image named transformed image to be compared with the reference image is displaced by (**X= -15, Y=10**) from the center of the first and rotated by **R= -10** degree.

The population size in each generation is restricted to 80 individuals with the crossover probability of 0.85 and mutation probability of 0.03. GA meets the criterion within 200 generations. In this work, we have used elitism technique for conserving the best solutions obtained in the optimization process. It is an effective tool to improve the performance capability of GA, because it prevents losing the best found solutions. At each generation, the best 5 individuals are preserved and copied into the next generation.

Figs. 3 and 4 illustrate the performance of GAs process during the run. From Fig. 3, we see that the best value of fitness is decreased or minimized from generation to another until generation 130, the value become stabilized around a value which correspond to optimal solution founded. Fig. 4 depicted the evaluation of the parameters (R,X,Y) during the generations. The red dashed lines show the initial parameters and blue lines show the optimal parameters found during the run the GAs. We see that the optimal parameters values are closer to the initial parameters.

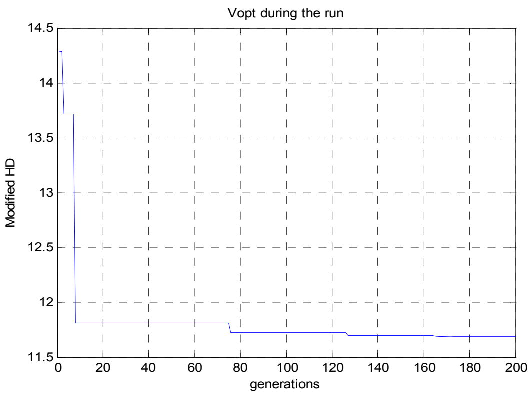


Fig. 3 Evolution of the candidate solution during the run of GAs

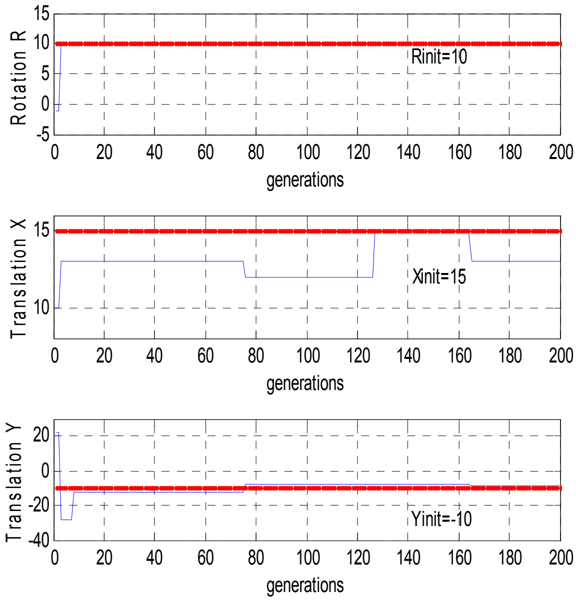


Fig. 4 Evolution of the parameters of transformation during the run of GAs

The input image and the reference image to be aligned and the resulting image corrected with the parameters found with the GAs process are shown in Fig. 5 with the size of 300*300 pixels.

A weighted Euclidean distance between an approximate and the exact solution is used throughout this paper to measure the accuracy of the obtained solution:

$$\delta = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta R}{R}\right)^2} \qquad (5)$$

where ΔX, ΔY, and ΔR are the difference between the approximate and the exact solution values of *X*, *Y* and *R*.

To improve the robustness of our algorithm, we have applied to register a pair of IKONOS images in which the second image is transformed with the same initial parameters without and with presence of noise.

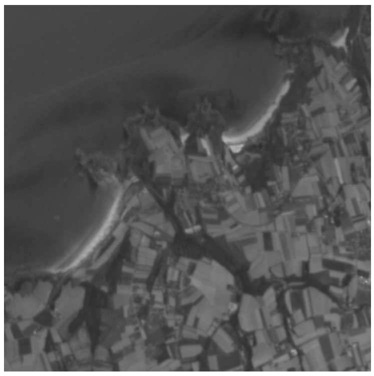
The analytical results of registration obtained with different images are depicted in Table I. Clearly, the obtained results are really promising as well as even in presence of speckle noise. Fig. 6 shows the image registration results of IKONOS images in the case of presence of noise with our proposed method.

TABLE I
ANALYTICAL RESULTS OF OBTAINED TRANSFORMATION PARAMETERS OF THE PROPOSED REGISTRATION METHOD FOR DIFFERENT IMAGES

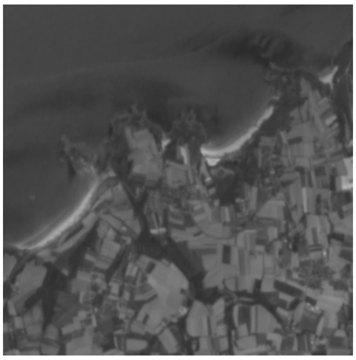
	Parameters found with GA			Error			δ
	R	Tx	Ty	ΔR	ΔX	ΔY	
SPOT	10	13	-9	0	2	1	0.1667
IKONOS	10	15	-9	0	0	1	0.1000
IKONOS + Noise	10	16	-11	0	1	1	0.1202

The work in [15], we propose a 2D point registration method based on the genetic algorithms. The basic idea is to find the optimal rigid transformation parameters with a two sets of points extracted from the images to be compared. We utilize a multi-resolution multi-directional transform to extract the control point sets and a distance metric to measure the goodness of the transformation parameters. The results prove the effectiveness of this approach compared to the intensity based registration method. In this context, we have conducted to a comparison between this approach and the proposed method based on the Hausdorff distance and corners detection. The results of the 2D approach presented in [15] are depicted in table II applied on the SPOT and IKONOS images with the same initial parameters of transformation.

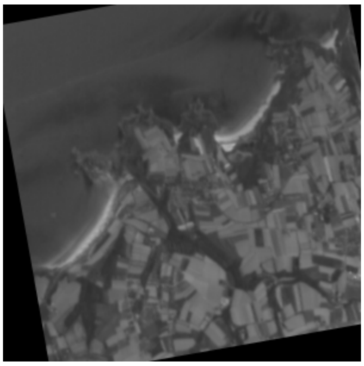
From the results of both tables, the values of error δ are slightly different from the obtained ones but in presence of bruit the value are increased. We can conclude that the proposed method based on the Hausdorff distance is less sensitive to bruit then is more suitable and effective for point set registration.



(a)



(b)



(c)

Fig. 5 Registration results of proposed method of SPOT images: (a) reference image which is referred to the model set M, (b) input image to be corrected which is referred to the model set S, and (c) registered image with obtained parameters transformation using GAs process

(a)

(b)

(c)

Fig. 6 Registration results of IKONOS images with the proposed method: (a) the reference image, (b) input image to be corrected in which we have added a speckle noise, (c) the registered image with the proposed GAs method

TABLE II
ANALYTICAL RESULTS OF 2D REGISTRATION METHOD OBTAINED WITH DIFFERENT IMAGES

	Parameters found with GA			Error			δ
	R	Tx	Ty	ΔR	ΔX	ΔY	
SPOT	11	16	-10	1	1	0	0.1183
IKONOS	10	17	-9	0	2	1	0.1666
IKONOS + Noise	10	16	-13	1	1	3	0.3065

VI. CONCLUSION

Point set registration is among the most fundamental problems in vision research. It is widely used in areas such as range data fusion, image alignment especially for medical images, object localization and recognition, and tracking.

The contribution of this paper is to present a rigid point set registration method for remote sensing images using Hausdorff distance and GAs. Unlike the other methods that match two intensity images, the proposed method can match the set of data extracted from image.

First a set of control points are estimated using corner detector based on Canny edge and therefore refined with correlation method in order to remove the false matching. A modified Hausdorff distance is adopted as a similarity measure between the two generated data sets and GAs is used as searching strategy to optimize the transformation parameters. The algorithm is applied for registering SPOT images as well as High resolution satellite images which is tedious in practice to process the geometric correction. The Experimental results are very promising as even in presence of noise.

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